MIT LIBRARIES
3 9080 00679046 0

INSTITUTE of TECHNOLOGY

HD28
.M414
no.
3005-
89

MASS. INST. TECH.
MAY 9 1991
LIBRARIES

MANAGING INNOVATION IN THE MANUFACTURING ENVIRONMENT: CREATING FORUMS FOR CHANGE ON THE FACTORY FLOOR

Marcie J. Tyre

WP#3005-89-BPS March, 1989
Revised December, 1989

M.I.T. LIBRARIES
MAY 09 1991
RECEIVED

ABSTRACT

This paper focuses on the process of introducing new production technologies into existing plants. It describes results from a study of 48 new process introduction projects in a leading global manufacturing company. Extensive quantitative and qualitative data were collected on the characteristics of the change in each case, the activities undertaken in response to the change, and the success of the introduction effort. The paper concludes that to respond effectively to the requirements of process innovation while simultaneously attending to the demands of an ongoing manufacturing operation, managers need to develop "forums for change" in the factory. Such forums are partially removed from the daily demands of the operating line. They make it possible for plant personnel to step back temporarily from the production process in order to reflect and build on their experiences with the new technology.

Further, this paper identifies some of the project design strategies through which managers create forums for change in the manufacturing environment. Drawing on examples from the cases studied, the author argues that these strategies for managing change create effective learning environments by serving to: 1) Focus attention on learning and problem solving; 2) Provide protected environments for developing and testing new ideas; 3) Bring diverse perspectives to problem definition and resolution; and 4) Multiply the resources, both physical and intellectual, available to the introduction project.

INTRODUCTION: THE NATURE OF TECHNOLOGICAL PROCESS CHANGE

Managing the process of technological change within the manufacturing domain presents special problems to managers. New process introductions put unfamiliar demands on existing systems and routines: the new technology may not fit with existing production processes; it may require new skills or procedures; or it may draw on knowledge bases or organizational linkages which do not exist in the factory [Leonard-Barton, 1987; Abernathy and Clark, 1985; Van de Ven, 1976]. The problems posed may be unfamiliar and even ill-structured. Indeed, researchers and practitioners have begun to accept that introducing new manufacturing technology is not simply a question of implementing a well-developed solution, but of managing a problem solving process to adapt existing ideas and create new solutions within a particular environment [Tyre, 1988; Kazanjian and Drazin, 1986; Rice and Rogers, 1980]. As argued by Leonard-Barton [1987], "implementation <u>is</u> innovation".

At the same time, however, the organizational task associated with ongoing operations involves applying existing routines to produce products in a predictable, efficient, and accurate manner. Factory routines are embedded in existing process equipment, in the training and skills base of plant personnel, and in standard operating procedures. These routine procedures become virtually automatic responses to a familiar and easily recognizable set of cues in the factory environment [Hedberg et al., 1976; March and Simon, 1958]. Integrating a new process technology into ongoing operations, therefore, requires the organization to respond to two different and frequently conflicting sets of demands [Skinner, 1986; Maidique and Hayes, 1984; Abernathy, 1978].

The tension between the demand for efficiency and the need for creativity and adaptability is central to the problem of managing innovation [Quinn, 1980; Morton, 1971]. However, this tension is particularly acute when factories attempt to introduce new process technologies. While a new machine may be conceived in a remote lab, it must be made to work in the factory. During the introduction process, the tasks of developing new ideas and of preserving the integrity of the existing system must be carried out in close proximity [Kazanjian and Drazin, 1986; Normann, 1977].

The result, in too many cases, is that introducing new process technology becomes a costly process which yields disappointing results. Recent studies have shown that plants introducing new process equipment often experience disruptions to ongoing productivity which cost them more than the original purchase of the equipment [Chew, 1985; Hayes and Clark, 1985]. Unsolved problems frequently persist for years. And even once the new technology is "up and running" performance improvements frequently fall far short of earlier expectations, or fail to address the realities of the new competitive environment [Economist, 1988; Jaikumar, 1986].

Unfortunately, we know very little about how to respond simultaneously to the dual needs of ongoing operations and the introduction of new process technology. Most research on "implementing" new technologies has focused on the need to create acceptance for the change within the new user organization, whether by means of managerial control [e.g. Zaltman et.al, 1973; Sapolsky, 1967] or through the involvement of users and the enthusiasm of technology "champions" [Johnson and Rice, 1987; Nutt, 1987; Maidique,

1980]. Only recently have researchers begun to model the process as one of ongoing innovation and problem solving, both technical and organizational, around an original concept [Leonard-Barton, 1987, Van de Ven, 1986; Rice and Rogers, 1980]. But researchers have so far not fully addressed the barriers to problem solving which exist in the production environment.

As used here, "problem solving" refers to the set of activities involved in adapting or redefining both the new technology and the existing productive system. In a typical new process introduction, for example, problem solving activities may include modification of machine elements, software development, creation of suitable tooling, training and skills development, revision of existing factory procedures, etc. This paper is intended to explore the organizational mechanisms that support and facilitate problem solving at the plant level; it does not analyze the specific subactivities and methodologies involved.

The paper is based on a recent field study of 48 new process introduction projects. Both quantitative and qualitative information was collected, using interviews, questionnaires, and archival data sources. Introduction projects were characterized in terms of the nature of the change involved and the project design strategies undertaken. Project success was also measured, in terms of 1) the time required for start-up and 2) the performance improvement and reliability achieved. The research was conducted in a leading manufacturing company and involved eight plants in the United States, West Germany, and Italy. The changes studied ranged from minor refinements to fundamental departures from existing manufacturing processes. Research took place over approximately one and one-half years from the fall of 1986 to the

spring of 1988. The study is described in detail in Tyre and Hauptman [1989].

PROCESS CHANGE AND TECHNOLOGICAL PROBLEM SOLVING

Based on the evidence gathered from these introduction projects, problem solving at the factory level is critical to successful process change, even when the degree of change is relatively small. For instance, describing one introduction which was rated near the bottom of the group in terms of novelty, a project manager explained:

> From a managerial point of view, this was not a major happening. However, out on the plant floor a lot of subtle adaptations were necessary for this introduction to be a success. Most important, the people involved had to figure out how to make use of the improved information capabilities.

At the other end of the spectrum was the introduction of a material forming system which represented a fundamental departure from traditional metal shaping techniques. According to the project manager:

> In the course of the two years following initial start-up, we had to change virtually everything except the raw material. We developed new tooling systems, cooling mechanism, processing operations -- even the way we think about processing parts in a system like this. It was like having a research project, not just a new production machine.

THE CONFLICTING REQUIREMENTS OF PROBLEM SOLVING AND PRODUCTION

In general, problem solving can be described in more or less sequential steps, including 1) collect performance data; 2) identify gaps between actual and desired performance levels; 3) formulate hypotheses about the causes of

performance gaps; 4) generate possible solutions; 5) choose among solutions; 6) prepare the chosen solution; 7) test the new solution and; 8) evaluate results. Achievement of an acceptable solution may require multiple iterations through this problem solving cycle, and any one introduction project is likely to present a (possibly very large) number of discreet or related problems.

To undertake these activities, the organization must invest time, attention, capital and manufacturing capacity in developing, trying, and evaluating alternative solutions. Unfortunately, this requirement is often in direct conflict with the priorities and assumptions that govern ongoing production. While it has become fashionable to describe factories as dynamic learning environments [e.g. Bohn, 1987], it has also become clear that learning does not occur naturally in the production environment [e.g. Dutton and Thomas, 1984]. Five sources of conflict appear to be particularly salient. They are:

A. The direct and indirect costs of problem solving in the manufacturing environment;

B. Opportunity costs associated with problem solving;

C. Managerial decisions about the way production is carried out;

D. Uncertainty of payoffs from problem solving;

E. The cognitive demands of problem solving compared to those of "business-as-usual".

A. Direct and Indirect Costs: Consider a common problem solving activity in the projects studied: developing a new tooling design. Costs were incurred in designing, fabricating or purchasing, and setting the new tool on

the machine. In addition, testing imposed additional but hard to predict costs in the form of disruption to regular production. Operators or setters had to adjust to subtle changes in their routines. If the test yielded negative results -- no matter how instructive those results might be -- costs were incurred in the form of increased scrap, confusion at downstream operations, and missed or late orders.

B. Opportunity Costs: Problem solving activities competed with production operations for precious resources, in particular for the time of engineering and technical support personnel. For example, studying, drafting, fabricating, and testing a new tool design required considerable investments of time from process engineers, tool designers, tool shop personnel, and other technicians. To the extent they invested in problem solving, technical and support personnel were unavailable for responding to other immediate needs in the plant. Indeed, in many projects efforts to develop specific solutions were consistently interrupted for "fire-fighting" on the line. As a result, underlying causes of process problems were never identified or addressed.

C. Management of Production Operations: In many plants, managerial decisions about production priorities exaggerated both direct and opportunity costs of problem solving. Slow machine setup capability, insufficient numbers of technical support personnel, chaotic demands on key production personnel, and slow response times made developing and testing process improvements a difficult and expensive undertaking. As one production supervisor pointed out:

> It was chaos around here during the whole time we were trying to develop a tooling package for the new system. First, every new setup took about half a day -- multiply that times two for each tool test. Then, every time we ordered a new tool, it arrived with some defect or problem. Keep in mind that the tool shop is half way across the plant, and the testing lab is clear at the other end. I spent most of my time for nine months running from one place to another.

Staffing and scheduling choices can add to the difficulty. For instance, while production was often staffed to be performed around the clock, technical support was generally available on only one shift. As one project participant exclaimed, "We really needed people capable of looking at and understanding what was going wrong on all three shifts, but the personnel and training just were not available."

In short, the plant was not being managed as if testing, experimentation, and problem solving mattered. As a result, production and problem solving both suffered.

D. Uncertain Payoff and Timing: The benefits of trying a new potential solution may be substantial -- but they are neither immediate nor predictable, and any individual iteration may yield no direct improvement at all. In some cases problem solving efforts were discontinued because no obvious improvements has been achieved in a given period of time; management was unwilling to continue iterative testing until a good solution was achieved. Impatience for results was often aggravated by excessive "lead times" to run a test; for example, the time required to develop, design, build, and finally set up to try a new tool on the machine. As one project member pointed out:

Getting new devices delivered took too long, and once they arrived we

would be so behind in production that there was no time to stop for a tool change. So, we were never able to translate our experience with this equipment into good solutions to our problems.

In situations like this one, problem solving soon became too troublesome to continue in the face of daily production demands. Factories instead accepted disappointing performance from new process equipment, decreasing the level of precision or variety demanded from the new operation. The cost of these decisions may have been significant, but was never measured.

E. Cognitive Demands: Finally, problem solving and production tended to conflict because they require different cognitive orientations. Because human information processing capacities are limited, people can attend only to some aspects of the environment. Which environmental variables gain their attention is determined largely by established habits and procedures [Cyert and March, 1963]. However, effective problem solving in the cases studied often required focusing on an unfamiliar set of variables, or measuring and describing familiar variables in a different or more precise way, or interpreting production results in a new light. In many cases where change was significant, established procedures for recording, communicating, and analyzing production information were no longer applicable, yet underlying systems did not change.

Further, problem solving demands a whole different level of attention than does ongoing production. Under normal circumstances actions are largely automatic; underlying causal models can be ignored, and efficiency is maximized. But in order to identify and understand problems which are not routine, individuals need to be willing to review and adjust their mental models and assumptions. As Dutton and Thomas [1984] point out, learning in

the manufacturing environment "does not depend on trial-and-error; it depends on insight" [p. 228].

However, once actors accept a given set of assumptions about the way the world works, they cease to examine those assumptions at a conscious level [Cyert and March, 1963]. Faced with the pressures of day-to-day demands, managers and other organizational actors choose not to seek out information which might disconfirm existing assumptions [Einhorn and Hogarth, 1977; Hall, 1976] or even recognize such information when it is available [Kiesler and Sproull, 1982]. These tendencies were reflected in the difficulties reported by project participants in examining the choices and assumptions embedded in new process equipment. As one project engineer explained in retrospect:

> We wasted a huge amount of time fixing problems on the plant floor instead of attacking the real issues at the level of the technology. We would make some small adjustment but then, due to difficulties at a more basic level, something else would happen such as a tool or a spindle would break. Then we would waste more time fixing that, or waiting for it to be fixed. The whole process accomplished very little until we were able to rethink some of the early choices and assumptions.

BUILDING ENVIRONMENTS FOR INNOVATION: THE ROLE OF FORUMS FOR CHANG

This and other cases illustrate that solving problems in a new process introduction frequently requires a different set of assumptions and behavior patterns from traditional approaches to production management. On the other hand, the problem solving process cannot be managed independently from production; the very focus of problem solving is the integration of the new technology with the existing system.

Indeed, in the successful introduction projects studied here, analysis and

problem solving were closely linked to action on the plant floor. New information about production operations was a critical input into the problem solving process. In many cases technical personnel depended on direct observation for defining the process and the problems occurring there. In other cases engineers depended on production personnel for feedback and suggestions, but still needed to bring a deep understanding of the production process to their analyses. Production personnel, in turn, had to understand what testing procedures were needed, and how changes would affect operations. Close coordination across functions was important for balancing opportunities for testing with demands for production. Production techniques which were consistent with testing routines had to be in place or developed.

However the very intimacy between production and problem solving posed a constant threat to introduction projects. When one group was simultaneously responsible for production and problem solving, it was easy for the time and attention needed for problem solving to be overwhelmed by the demands of maintaining routine production. In one case, for example, a project engineer explained:

> All the burden fell on us at once: to produce parts, work with operators, prepare new tools, see to maintenance, design new machine components, and to have new ideas. But once we got the equipment into the factory, time to do important engineering work was squeezed out by everyday work to keep things running. The result was lots of lost time and grey hair!

For all these reasons, genuine problem solving requires the ability to step back, temporarily, from the pressures of the regular production process. In successful projects, managers used various mechanisms to create what might be called "forums for change" where project participants could gather and

reflect on data, formulate new questions, and develop new solutions.

One of the projects studied provides a striking illustration of this concept. The project involved the introduction of programmable robots into a traditional finishing and assembly line. When the equipment was delivered, it was set up close to the line where it would later be installed. But for two months the robotic cell was separated from the line by temporary, half-height plywood partitions. The partitions defined a unique space reserved for testing and developing the new technology; in effect, the project group had physically constructed a semi-bounded forum for problem solving on the shop floor. Plant personnel referred to the space as "the development box".

Inside the development box, the robot ran a simulated production sequence while the project leader -- an expert operator/setter who had been trained in robot technology and who had helped to design and select the system -- watched, studied, and adapted the equipment and software. At first, the project leader worked with technical people from the equipment vendors and with the production supervisor on the line. As the problems he faced became increasingly specific, he collaborated more closely with specialists in the plant technical office to develop new ideas or to test new sequences.

The development box offered several benefits. First, solutions were formulated in close proximity to the production line -- and because the project leader had been an expert operator, his observations reflected a deep understanding of the existing production process. Further, people and information moved freely between the production line, the development box, and the engineering office. In fact, no one in the plant was very sure if

the project leader himself was part of the production group, or was a member of the plant technical staff. Yet the relatively protected environment of the development box sheltered the group while it conceived new solutions, ran trials, and made and examined mistakes.

According to the department manager, "once we put the new cell into regular operation, we discovered lots of ways to improve the process. But because of what we had learned already, putting improvements in place did not require any major changes". Total start-up time was one of the shortest recorded, and performance of the technology was considered outstanding.

Other studies have also discovered the power of a "development box" for facilitating problem solving on the factory environment. For instance, in their study of highly innovative projects undertaken by Japanese companies, Imai et.al [1985] note that, "Honda fostered learning within the production group by establishing a special corner within the factory where rank-and-file workers could experiment with work simplification ideas".

The development box provides a potent metaphor for the management of process change. While project teams could not always erect plywood partitions around the new equipment, successful teams did create temporary, highly malleable forums for learning about new process technologies. The boundaries of these forums were permeable; people and ideas could move across functional, organizational, and disciplinary delineations. Actual operating results provided information for defining problems and opportunities, and for testing new solutions. But problem solving activities were set off from regular production processes, either because they occurred prior to actual

production start-up, or were situated physically apart from ongoing production operations, or brought new perspectives from individuals not involved in day-to-day operations. Project participants therefore had the opportunity to shape focused agendas for experimentation, and to do so in a way which minimized disruption to the line. They were forced to consider not just "How do I fix what's going wrong?" but rather "What is going wrong -- or could go wrong -- and why?"

ORGANIZATIONAL MECHANISMS FOR CREATING FORUMS FOR CHANGE

This study identified three organizational response mechanisms which enabled plant personnel to build forums for change in support of new process introductions. They are 1) preparatory, or early, search undertaken before the new technology is put into use; 2) joint search during the startup process with technical experts outside the factory, and 3) functional overlap between engineering and manufacturing groups at the plant level. All three response mechanisms involve cooperative problem solving activities undertaken across different functions, different disciplines, or different organizational entities. While these mechanisms have been treated individually in earlier research, this study links them and confirms their importance for the management of technological change.

Preparatory search measures the degree to which project personnel at the plant level undertook explicit activities to modify both the new technology and the existing production system before delivery or installation of the new technology. Activities measured include cooperation with technical managers

in the initial definition of the new technology, subsequent work with equipment suppliers on the development and testing of new concepts and techniques, and development of complementary systems and components in conjunction with outside or internal component suppliers.

Investing in preparatory search created a forum for change even before the new equipment was installed. By definition, activities were separated in time from the actual production work with the new technology. Further, they often took place outside of the factory, at a vendor or research facility, or away from the production line within the plant. Yet early problem solving activities involved production and engineering personnel who brought experience with the existing process to the development of the new technology.

The individuals involved in these efforts served as a sort of early scouting party. By working with vendors and suppliers during the early stages of the project, they created linkages between the plant and a wider network of technical resources. When modifications were identified during specification or development of the new system, they were generally easier and cheaper to carry out than changes made during production start-up. New ideas could be tried without the risk of disrupting production. Experiments could be repeated rapidly and cheaply. By working with outsiders, project participants came into contact with new perspectives on the nature of problems and possible solutions.

Finally, such activities were governed by a different set of objectives and assumptions than was true for normal production. During the preparatory

period, project members explicitly were trying to seek out potential problems, and to search for possible untried solutions. As one project manager commented in describing a very successful introduction:

> In this project, we made the commitment up front to develop new solutions, and we did that before we had to deal with the problem of the actual plant start-up. The most important thing was that, during this period, our minds were free.

The two other response mechanisms identified involve cooperative work which took place during the actual start-up of the new process in the factory. Joint search measures the degree to which plant-level personnel worked together with outside sources of technical expertise in the process of introducing the new technology. Outside experts are defined to include personnel from technical facilities or sister plants within the same company, as well as external equipment vendors or component suppliers.

Joint search appeared to serve several functions in the problem solving process. First, because outsiders were available only temporarily and typically were involved for a specific reason, their participation signalled a change from business-as-usual to an explicit focus on problem identification and solving. As one project manager explained, "When Alfredo was here, the time we spent was short but it was intense. We came together and concentrated on the most important problems that had hampered the initial start-up."

The physical location of joint activities also served to underline this difference between routine operations and explicit problem solving. In many cases, plant personnel visited outside labs or production facilities to

discuss problems; in others, where outside partners visited the production plant, the joint team often set up an off-line workshop or meeting area where they could analyze recent events and discuss possible courses of action. Regular meetings made it possible to review individual events in a wider perspective.

These working partnerships also provided opportunities for trying new ideas in a protected, low-risk environment. In many cases relationships with outsiders gave plant personnel access to pilot lines or specialized testing facilities that could not be replicated in the plant. Further, by sharing their different areas of expertise, joint problem solving teams could more fully evaluate potential new solutions even before investing in development and physical trials. According to one project participant:

> By working together, we were able to do a great deal of mental testing of the ideas suggested by us and by our tooling suppliers. Understanding all of the implications of a certain tool design is a very complex process. We could not have done it alone.

Equally important, the participation of outside experts forced project participants to step away from normal procedures and assumptions which were taken for granted within the plant environment. As one project leader explained:

> At the start we only had experience with regular honing, so we really did not believe that a honing machine could be used for this kind of work. [But our supplier's] understanding of honing stones and shaft designs helped us to understand test results in a different way. The experience of working with this supplier has changed our notions of what a honing machine can do.

Finally, bringing in outside experts multiplied the physical and intellectual resources available to the introduction effort. Without such resources, factories frequently would not have been able to afford the apparent luxury of taking time for building knowledge, instead of making parts.

Functional overlap measures the degree to which the roles and responsibilities of technical and production personnel within the plant were merged for the purposes of introducing the new technology. Where overlap was high, technical decision making and actual production responsibility was closely linked. But at the same time, overlap created opportunities for the people most closely involved in the day-to-day functioning of the new technology to step back from the process to examine results and to consider appropriate actions.

For example, in one introduction the traditional distinction between technical staff and manufacturing line personnel was replaced by a team concept. Direct production responsibility on each shift was shared by a process engineer, a maintenance engineer, and an expert tool setter. Each member of this production team kept a daily log of problems or irregularities in and around the new process. Each week the entire project group -- including the department manager, technical specialists, and production team members -- met to investigate problems. Meetings were scheduled so that there would be time to investigate a given issue in depth. They were held in the factory, but in an office away from the production line. In addition, the functional regrouping sent an important signal to project participants that the introduction represented a change from normal roles and routines.

The project manager explained:

> During these meetings we used the daily production logs and other observations to study the pattern of events over days or weeks of production. In the process, it was important to get the opinion of each person in the group. Each had an input into the final decision, but the final decision could not have come from any one person. That's how we traced a lot of problems to their source.

By bringing together multiple perspectives within the plant, these meetings spawned new ways of looking at problems or opportunities. As one member of such a group pointed out,

> On day one, each person working on this project brought a specific area of expertise. On day 100, every person was an expert in the system. That required a lot of cross-learning, but it was necessary to develop the new kinds of insights this technology demands.

FORUMS FOR CHANGE: THE KEYS TO PROJECT SUCCESS

The descriptive evidence presented above suggests that organizational response mechanisms that brought together diverse perspectives to form semi-bounded forums were important vehicles for problem solving in new process introductions. This idea is further supported by quantitative analysis of project success. For every project studied, two outcome parameters were estimated: first, the elapsed time between installation of the new process equipment and completion of the introduction process, and second, the degree of operating improvement achieved with the new equipment. Further, in order to control for differences in the size and difficulty of introduction projects, estimates of the technical novelty and scale of the new technology, as well as a measure of the required shift in existing manufacturing systems, were included in the analysis.[1]

The results of a multiple regression analysis are shown in Table 1. Results support the idea that the response mechanisms identified contribute significantly to project success. Higher levels of preparatory search, joint search, and functional overlap are each associated with significantly shorter start-up times. Similarly, both preparatory search and joint search contribute significantly to reported performance improvements. The contribution of functional overlap, while positive, is not statistically

---

[1] See Tyre and Hauptman [1989] for an explanation of variables. Other factors which have been shown to affect implementation success, such as team motivation, managerial support, and technical expertise were also investigated. However, because these latter factors did not affect conclusions about the role of project strategies, they are excluded from the following discussion.

Table 1

RELATIONSHIP BETWEEN USE OF PROJECT STRATEGIES

AND PROJECT SUCCESS

Dependent Variable: START-UP TIME

Independent Variables:

PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP	TECHNICAL NOVELTY	SYSTEMS SHIFT	PROJECT SCALE	
-.41** (.09)	-.35** (.10)	-.33** (.14)	.54** (.09)	.74** (.13)	.32** (.11)	R^2= df=

Dependent Variable: OPERATING PERFORMANCE

Independent Variables:

PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP	TECHNICAL NOVELTY	SYSTEMS SHIFT	PROJECT SCALE	
.47** (.13)	.30** (.14)	.28 (.20)	-.25* (.13)	-.27 (.18)	-.23 (.16)	R^2= df=

Regression coefficients are standardized to facilitate comparison of effect sizes. Estimated standard errors of standardized regression coefficients are shown in parentheses:

** = Coefficient significant at .05 confidence level

* = Coefficient significant at .10 confidence level

significant. (For further examination of the role of functional overlap, see Tyre and Hauptman [1989].)

Further, the evidence suggests that a failure to use organizational mechanisms that foster forums for change may contribute to the relatively poor performance of some U.S. operations in introducing new process technology. Table 2 examines the gap between U.S. and European performance i the projects studied. The first two equations show the effect of a "dummy" variable representing U.S.-based projects, ignoring differences in the way the project strategies were used. In both equations, the U.S. "dummy" is associated with significant performance decrements; on average, new process introductions in the U.S. plants took almost 40% longer to accomplish than was true for European plants, and performance improvements achieved were estimated to be almost 50% better in Europe than in the U.S.

Significantly, these relationships change when we take into account the actual levels of preparatory search, joint search, and functional overlap in each project. The second set of equations in Table 2 show that when the use of these design strategies is considered, differences between project performance in Europe and the U.S. are not statistically significant. That is, what seemed at first to be vague regional differences in performance now appear to be attributable, in part, to specific choices made by managers in each country about how much effort to invest in preparatory search, joint search, and functional overlap. (These differences are more fully examined in Tyre, 1989.)

Table 2

RELATIONSHIP BETWEEN GEOGRAPHIC REGION AND PROJECT SUCCES

I. DISREGARDING USE OF PROJECT DESIGN STRATEGIES:

Dependent Variable: STARTUP TIME

TECHNICAL NOVELTY	SYSTEMS SHIFT	PROJECT SCALE	U.S. DUMMY	
.50**	.30**	.16	.30**	R^2=.40
(.11)	(.11)	(.12)	(.12)	df= 43

Dependent Variables: OPERATING PERFORMANCE

TECHNICAL NOVELTY	SYSTEMS SHIFT	PROJECT SCALE	U.S. DUMMY	
-.23	.13	-.10	-.33**	R^2=.10
(.14)	(.14)	(.15)	(.15)	df= 43

II. CONTROLLING FOR USE OF PROJECT DESIGN STRATEGIES

Dependent Variable: STARTUP TIME

PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP	TECHNICAL NOVELTY	SYSTEMS-SHIFT	PROJECT SCALE	U.S. DUMMY	
-.39**	-.33**	-.28**	.54**	.69**	.32**	.11	
(.09)	(.10)	(.14)	(.09)	(.14)	(.07)	(.10)	
							R^2=.64
							df= 40

Dependent Variable: OPERATING PERFORMANCE

PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP	TECHNICAL NOVELTY	SYSTEMS SHIFT	PROJECT SCALE	U.S. DUMMY	
.45**	.27**	.20	-.25**	-.20	.25	-.16	
(.13)	(.14)	(.20)	(.13)	(.19)	(.15)	(.10)	
							R^2=.31
							df= 40

Regression coefficients are standardized to facilitate comparisons. Estimated standard error of standardized regression coefficients are shown in parentheses:

**= Coefficient significant at .05 confidence level

* = Coefficient significant at .10 confidence level

CONCLUSION: MANAGING INNOVATION THROUGH FORUMS FOR CHANGE

This paper suggests that problem solving at the plant level is critical when factories undertake technological process change. Yet the discussion here shows that there are powerful reasons why genuine problem solving is often driven out by the demands of "business-as-usual". In order to focus on the issues and problems of the new technology, plant personnel must be able to step back from their normal behavior patterns and assumptions. They need to create forums where they can focus on the problems of change, but still remain in contact with the needs of the ongoing process.

This paper identified three organizational response mechanisms which appear to support the dual needs of successful new process introductions. Qualitative evidence suggests the interrelated ways in which these mechanisms enabled participants to build forums for change in the plant environment. First, they provided a way to focus the attention of plant personnel on explicit problem solving, not just routine production. Second, they helped to create protected environments for developing and testing new ideas. Third, by bringing diverse perspectives to problem definition and resolution, these mechanism forced the individuals involved to examine and adjust existing assumptions. And finally, such activities multiplied the resources, both physical and intellectual, available to the introduction project.

These findings are significant not only for the management of technological change in the manufacturing environment, but also for the more general problem of change in organizations. Metcalf [1981], for instance, argues that temporary, cross-area working groups can be important agents of

change for many of the same reasons outlined above. Metcalf suggests that,

> Detached temporarily from their established roles, and without committing their constituents, individuals drawn from the various publics can explore the consequences of untested strategies and alternative designs... the working party's composition cuts across conventional categories and provides the participants with a continuing forum in which collectively to think through the interconnected problems of change [Metcalf, 1981; p. 514].

Lanzara [1983] examines the more extreme problems of organizational adaptation to crises or disasters. He found that successful groups created opportunities for learning, action, and adaptation amidst the chaos by forming "zones of freedom" or "zones of certainty" to work within. In effect, these small working groups walled off a relatively narrow sphere of action where they could experiment, using existing skills and capacities in new ways and combinations. As they gained experience, they adapted their skills and even their ways of understanding to the changed environment. Quoting Stone [1981], Lanzara points out that these groups were successful not because they abandoned existing ways, but because they were "juxtaposing (previous) experiences in new ways, making analogies, and gaining new insights" [page 3] into how to connect the old with the new.

Lanzara's adaptive groups were characterized by fuzzy boundaries, fragmented authority, and "sideways" as opposed to bureaucratic relationships. As such they often threatened traditional bureaucratic structures, and Lanzara points out that their success was frequently cut short when existing official structures, rules, and constraints were forced upon them. "Intersection with the bureaucracy was lethal" for these experimenting organizations (page 83).

Lanzara, Metcalf, and others argue that if formal organizations are to thrive in a changing environment, they must learn to facilitate and nurture the creation of "forums for change". In these forums, individuals from different functions, groups, and organizations can use the assembled skills to create new capabilities and new ways of seeing and solving problems.

In this paper, I have discussed the importance of such forums for enabling technological change in the production process. Further, I have outlined some mechanisms that appear to contribute to the creation of such forums. Yet, as demonstrated, managers frequently fail to utilize these mechanisms. This is understandable. Preparatory search, joint search, and functional overlap all entail costs in the short term, and require concerted managerial guidance over the long run. Further, these mechanisms require the development of technical capabilities, organizational resources, and cooperative attitudes within the factory, across the corporation, and among its external partners. This author hopes that, in developing a clearer understanding of the organizational mechanisms which support the successful introduction of new process technologies, managers will show greater willingness to build, nurture, and reward such activities in their changing organizations.

REFERENCES

Abernathy, William J., The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry, Baltimore: Johns Hopkins University Press, 1978.

Abernathy, William J. and Kim B. Clark, "Innovation: Mapping the Winds of Creative Destruction," Research Policy, 1985.

Bohn, Roger E., "Learning by Experimentation in Manufacturing," Harvard Business School Working Paper 88-001, 1987.

Bright, James R., Automation and Management, Boston, MA: Harvard Business School Division of Research, 1958.

Chew, W. Bruce, "Productivity and Change: Understanding Productivity at the Factory Level," Paper for the 75th Anniversary Colloquium of the Harvard Business School, 1985.

Cyert, Richard M. and James G. March, A Behavioral Theory of the Firm, Englewood Cliffs, NJ: Prentice-Hall Inc., 1963.

Dutton, John M. and Annie Thomas, "Treating Progress Functions as a Managerial Opportunity," American Management Review 9 (2), 1984, 235-247.

Hall, Roger I., "A Systems Pathology of an Organization: The Rise and Fall of the Old Saturday Evening Post," Administrative Science Quarterly, Vol. 21, 1976, 185-211.

Hayes, Robert H. and Kim B. Clark, "Exploring the Sources of Productivity Differences at the Factory Level," in Clark et al. (eds.) The Uneasy Alliance, Boston, MA: Harvard Business School Press, 1985.

Hedberg, Bo, Paul Nystrom and William Starbuck, "Camping on Seesaws: Prescriptions for a Self-Designing Organization," Administrative Science Quarterly, Vol. 21, 1976, 41-65.

Hogarth, Robin M., Judgement and Choice: The Psychology of Decision Making, NY: John Wiley, 1980.

Jaikumar, Ramchandran, "Postindustrial Manufacturing," Harvard Business Review 64 (6), November-December 1986, 69-76.

Johnson, Bonnie and Ronald Rice, Managing Organizational Innovation: The Evolution from Word Processing to Office Information Systems, NY: Simon and Schuster, 1987.

Kazanjian, Robert K. and Robert Drazin, "Implementing Manufacturing Innovations: Critical Choices of Structure and Staffing Roles," Human Resource Management 25:30, 1986, 285-403.

Kiesler, Sara and Lee Sproull, "Managerial Response to Changing Environments: Perspectives on Problem Sensing from Social Cognition," Administrative Science Quarterly 27, December 1982, 548-570.

Lanzara, Giovani Francesco, "Ephemeral Organizations in Extreme Environments: Emergence, Strategy, and Extinction" Journal of Management Studies, 21, 1, 1983: 71-95.

Leonard-Barton, Dorothy, "Implementation as Mutual Adaptation of Technology and Organization" Working paper 88-016, Harvard University Graduate School of Business Administration, 1987.

Maidique, Modesto A., "Entrepreneurs, Champions, and Technological Innovation" Sloan Management Review Winter 21, N. 2, 1980, 59-76.

Maidique, Modesto A. and Robert H. Hayes, "The Art of High-Technology Management", Sloan Management Review 25 (2), Winter 1984, 17-31.

March, James G. and Herbert Simon, Organizations, New York: John Wiley and Sons, 1958.

Metcalf, Les, "Designing Precarious Partnerships" in Paul C. Nystrom and William Starbuck, (eds.) Handbook of Organizational Design Vol. 1, Oxford, England: Oxford University Press, 1981, 503-530.

Morton, Jack A., Organizing for Innovation, NY: McGraw Hill, 1971.

Normann, R., Management for Growth, NY: John Wiley, 1977.

Nutt, Paul C., "Tactics of Implementation," Academy of Management Journal 29 (2), 1986, 230-261.

Quinn, James Brian, "Managing Strategic Change," Sloan Management Review 21 (4), Summer 1980, 3-20.

Rice, Ronald E. and Everett Rogers, "Reinvention in the Innovation Process," Knowledge 1 (4), 1980, 499-514.

Sapolsky, Harvey, "Organizational Structure and Innovation," Journal of Business 40 (7), 1967, 497-510.

Skinner, Wickam, "The Productivity Paradox," Harvard Business Review 86 (4), July-August 1986, 55-59.

Stone, J. "Memory and Conversational Informatics: The Case for Productive Initiatives", paper presented at the Conference on Electronic Conversation, Milan, June 1981.

Tyre, Marcie J., and Oscar Hauptman, "Technological Change in the Production Process: Organizational Implications and Responses," Working Paper 3050-89-BPS, Massachusetts Institute of Technology, Sloan School of Management, July 1989.

Tyre, Marcie J., "Managing the Introduction of New Process Technology: An International Comparison," Working Paper 3004-89-BPS, Massachusetts Institute of Technology, Sloan School of Management, 1989.

Van de Ven, Andrew, "Central Problems in the Management of Innovation," Management Science 32 (5), 1986, 590-607.

Zaltman, Gerald, Robert B. Duncan, and Jonny Holbeck, Innovation in Organizations, New York: John Wiley and Sons, 1973.

5724 U50

Date Due

FEB 11 1992

NOV 25 1992

DEC 07 1993

APR 1 1 1994

Lib-26-67

MIT LIBRARIES DUPL

3 9080 00679046 0